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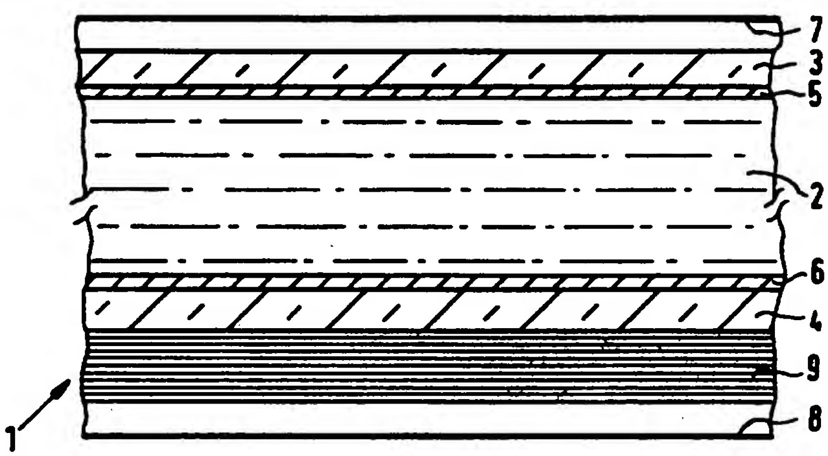
(54) Title: LIQUID CRYSTAL DISPLAY DEVICE AND RETARDATION FOIL

(57) Abstract

A liquid crystal display cell is provided with a compensation layer which, viewed transversely to the cell, has a broken (non-rotationally) symmetrical refractive index pattern or indicatrix. To obtain a small angle dependence, the associated birefringence of the compensation layer is complementary to that associated with a given voltage across the liquid crystal cell, so that the optical axis of the compensation layer substantially coincides with the direction of the directors in the driven state. The compensation layer can be manufactured in many different ways by making use of cholesteric foils or foils based on discotic LC materials.



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Liquid crystal display device and retardation foil.

The invention relates to a liquid crystal display device having a display cell which comprises a layer of nematic liquid crystal material between two substrates provided with electrodes, said cell being further provided with polarizers and comprising at least an optically anisotropic layer of a material having a cholesteric ordering between the polarizers. The invention also relates to a liquid crystal display device having a display cell which comprises a layer of nematic liquid crystal material between two parallel substrates provided with electrodes, said cell being further provided with polarizers and comprising at least an optically anisotropic layer of polymer material between the polarizers. The invention further relates to retardation foils for use in liquid crystal display devices.

Display devices of this type are generally used in, for example monitors, TV applications and, for example display devices in automobiles and for instruments.

A display device of the type described in the opening paragraph is known from USP 5,210,630. In this display device a compensation foil consisting of an optically anisotropic layer of polymer material with a cholesteric ordering is used to inhibit discoloration and obtain a high contrast in a twisted nematic display device. The polymer material is ordered in such a way that a molecular helix can be distinguished, with the axis of the helix being directed transversely to the layer.

However, display devices provided with such compensation foils still have a large viewing angle dependence, *i.e.* the contrast is very much dependent on the angle at which and the direction from which the display device is being watched.

It is, *inter alia* an object of the invention to provide a display device of the type described above in which the angle dependence is considerably reduced. It is also an object of the invention to provide a (retardation) foil which can be used in such display devices.

A first display device according to the invention comprising a liquid crystal display cell with a layer of nematic liquid crystal material which is present between two substrates provided with electrodes and comprises polarizers and at least an optically

anisotropic layer of a material having a cholesteric ordering between the polarizers is therefore characterized in that, viewed transversely to the substrates, the director profile in the optically anisotropic layer has a non-rotationally symmetrical pattern. This can be ascertained by means of conoscopy.

In this connection the phrase "director profile in the optically anisotropic layer" is understood to mean the director profile across a thickness of at least an entire height or pitch of the molecular helix. "Non-rotationally symmetrical" is herein understood to mean a pattern which does not exhibit any rotational symmetry and in which the finite thickness of the layer is not taken into consideration. The pattern may be symmetrical with respect to an arbitrary axis. In this application this will also be referred to as "broken (axial) symmetry". Due to this measure, the optical axis of the optically anisotropic layer extends at an angle to the axis transverse to the two substrates. The optical axis is herein understood to mean the direction having the smallest refractive index. In the above-mentioned polymer material having a molecular helix, the optical axis coincides with the axis of the helix.

A second display device according to the invention, comprising a liquid crystal display cell with a layer of nematic liquid crystal material which is present between two parallel substrates provided with electrodes and comprises polarizers and at least an optically anisotropic layer of a polymer material between the polarizers is characterized in that the optical axis of the optically anisotropic layer extends at an angle to a direction transverse to the substrates. In this case the optical axis need not have the same direction throughout the thickness of the anisotropic layer.

The invention is based on the recognition that in practice and at the customary voltage across the liquid crystal material, the directors in this material still extend at a small angle to the direction transverse to the substrates. Consequently, the birefringence for different viewing angles is different and is not symmetrical with respect to a direction perpendicular to the two substrates, which accounts for the angle dependence of a liquid crystal having a nematic structure. It is true that this angle dependence may be reduced by means of a compensation foil; however, when a compensation foil is used in the device as described above, in which the axis of the helix is directed transversely to the polymer layer, the compensation is optimal for an isotropic liquid crystal layer, *i.e.* a situation in which the directors are directed perpendicularly to the substrates. In practice, this situation occurs only at very high voltages (still disregarding the fact that the molecules are anchored on the substrates in such a way that this is impossible close to the substrates).

According to the invention, by choosing a non-rotationally symmetrical

pattern for the director profile in the optically anisotropic layer, the angle dependence of the total device is changed in such a way that light beams which have undergone a large birefringence in the liquid crystal (at a given drive voltage, the "given voltage") are more compensated by the birefringence in the compensation layer than light beams which have undergone a small birefringence in the liquid crystal. As it were, the optical axis in the compensation layer is now substantially parallel to the average direction of the directors in the layer of liquid crystal material. Dependent on the voltage chosen, this "broken symmetry" can be adapted in given implementations of the invention. The "given voltage" is preferably chosen to be such that the described compensation of birefringence occurs in a near-zero transmission range; for example, the voltage in the voltage/transmission characteristic at which 10% of the maximum transmission occurs is used for this purpose.

A "broken symmetry" transverse to the substrates (or an optical axis not transverse to the two substrates) can be obtained by providing a compensation foil as described in USP 5,210,630 at an angle to these substrates. This embodiment is characterized in that the director profile in the optically anisotropic layer is parallel to boundary surfaces of the optically anisotropic layer, and the optically anisotropic layer is provided at an angle to one of the substrates.

The same solution may also be used if the liquid crystal display device comprises as an optically anisotropic layer a layer of polymerized discotic liquid crystal materials. Examples of such discotic liquid crystal materials are given in "Discotic Liquid Crystal", Liquid Crystals 1993, vol. 14, no. 1, pp. 3-14. Such a display device is characterized in that the average direction of the director in the optically anisotropic layer is transverse to the boundary surfaces of the optically anisotropic layer, and the optically anisotropic layer is provided at an angle to one of the substrates. In this case, the direction of the director coincides with the optical axis. In both cases, said angle is between 1 and 30 degrees and is preferably approximately 10 degrees.

In practice, a display having such a tilted compensator will soon become too thick. A preferred embodiment of the display device according to the invention, with a cholesteric ordering in the anisotropic layer, is therefore characterized in that the director profile in at least a part of the optically anisotropic layer is provided at an angle to the substrates. Similarly, a preferred embodiment of the display device according to the invention, with polymerized discotic liquid crystal materials in the anisotropic layer, is characterized in that the director profile in at least a part of the optically anisotropic layer is provided at an angle to the direction transverse to the substrates.

The optically anisotropic layer preferably has a sawtooth structure on at least one of its boundary surfaces. In a device using a plurality of pixels, the pitch of the sawtooth structure is preferably of the order of the pixel size, or smaller.

If the two boundary surfaces are formed with a sawtooth structure, the sawtooth directions, *i.e.* the directions in which the separate teeth increase in thickness, can be rotated, for example 90° with respect to each other. Such a structure has a smaller retardation (difference in optical path length for the ordinary and extraordinary light beam, also expressed as $d.\Delta n$, with d: thickness of the material, Δn: optical anisotropy).

The broken symmetry can be obtained during manufacture by using polymer material obtained from a liquid crystal monomer. During the manufacture of one or both boundary surfaces, a pretilt can be imposed. Dependent on the choice of this pretilt, the optically anisotropic layer then acquires a "splay deformation". The ultimate director profile may also be influenced during manufacture by means of electric or magnetic fields, or both. This may result, for example in a preferred direction for the directors (cholesteric materials) or in a variation of the directors (discotic materials) in the anisotropic layer.

The optically anisotropic layer may alternatively consist of sub-layers; for example, the layer may comprise a uniaxial foil as a sub-layer. The director profile may also extend locally across only a part of the thickness of the layer.

A further preferred embodiment of a display device according to the invention, with a cholesteric ordering in the anisotropic layer, is characterized in that the pitch of the cholesteric material is smaller than 0.25 micrometer. It is thereby achieved that, for example the part of the s-polarized light which is converted by the cholesteric effect of the anisotropic layer into p-polarized light is as small as possible so that the number of grey tints to be realised is considerably increased.

A (retardation) foil according to the invention, comprising an optically anisotropic layer of a material having a cholesteric ordering, is characterized in that, viewed transversely to the foil, the director profile in the optically anisotropic layer has a non-rotationally symmetrical pattern.

A preferred embodiment is characterized in that the director profile in at least a part of the optically anisotropic layer is provided at an angle to the boundary surfaces. In this respect, the boundary surfaces are understood to mean the macroscopic boundary surfaces transverse to the normal on the foil, in which possible disturbances in smoothness, provided deliberately or not deliberately, (such as, for example a sawtooth structure as mentioned above) are not taken into consideration.

Another foil comprising an optically anisotropic layer of a polymer material is characterized in that the optical axis of the optically anisotropic layer extends at an angle to a direction transverse to the substrates.

A further preferred embodiment of such a foil is characterized in that the optically anisotropic layer comprises a layer of polymerized discotic liquid crystal materials.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

In the drawings:

Fig. 1 is a diagrammatic cross-section of a part of a liquid crystal display device according to the invention,

Fig. 2 shows a part of the device of Fig. 1,

Fig. 3 shows diagrammatically the optical behaviour of the device of Fig. 2, with indicatrices,

Fig. 4 shows diagrammatically a number of variants of the device of Fig. 1,

Fig. 5 shows the structure formula of a liquid crystal composition as used in an optically anisotropic layer with a cholesteric ordering,

Fig. 6 shows the possible external influence of the director pattern in such an optically anisotropic layer during its manufacture, while

Fig. 7 shows a possible distribution in the director pattern after such an external influence, and

Fig. 8 shows diagrammatically how the angle dependence is reduced by means of the optically anisotropic layer at different voltages in the transmission/voltage characteristic.

Fig. 1 is a diagrammatic cross-section of a part of a liquid crystal display device comprising a liquid crystal cell 1 with a twisted nematic liquid crystal material 2 being present between two substrates 3, 4 of, for example glass, provided with electrodes 5, 6. The device further comprises two polarizers 7, 8 whose direction of polarization is mutually crossed perpendicularly. The device further comprises orientation layers (not shown) which orient the liquid crystal material on the inner walls of the substrates, in this example in the direction of the axes of polarization of the polarizers, such that the cell has a twist angle of 90 degrees. In this case, the liquid crystal material has a positive optical

anisotropy and a positive dielectric anisotropy. If the electrodes 5, 6 are energized with an electric voltage, the molecules, and hence the directors, orient themselves to the field. In the ideal case, all molecules are thus substantially perpendicular to the two substrates (situation 11 in Fig. 2). However, in practice this situation requires a too high voltage; at customary voltages, the molecules extend at a smaller angle to the normal on the substrates 3, 4, corresponding to situation 12 in Fig. 2. From the direction 13 the viewing angle is rather in the direction of the molecules so that said angle dependence still occurs for light which is still transmitted at this voltage. This angle dependence may be explained by means of the "optical indicatrix", a three-dimensional geometric representation of the refractive index for each direction in which the vector of the electric field component of the light can oscillate. For optically isotropic material it is convex, for biaxial material it is an ellipsoid and for uniaxial material it is an ellipsoid having an axial symmetry. Since in the ideal case the liquid crystal material in the driven state is uniaxial substantially throughout its thickness (in substantially all molecule layers, except for some molecule layers near the substrates, the molecules are perpendicular to the substrates) the situation 11 of Fig. 2 can be represented by means of the indicatrix 14 in Fig. 3 with an ellipsoid shape and the principal axis transverse to the liquid crystal layer, the refractive index n_z perpendicular to the substrates being larger than that in the planes parallel to the substrates ($n_x = n_y$).

Since the liquid is not isotropic, there is birefringence. It can be shown that this birefringence can be compensated with an indicatrix 15 in Fig. 3 having an ellipsoid shape and an axis transverse to the liquid crystal layer, the refractive index n_z perpendicular to the substrates being smaller than that in the planes parallel to the substrates ($n_x = n_y$). The compensation layers as described in EP-A 0,372,973 may be manufactured in such a way that the associated indicatrix satisfies this. Such a compensation layer comprises a cholesteric material with the molecular axis of the helix being transverse to the layer, so that the director pattern, viewed transversely to the layer, is rotationally symmetrical.

For the more practical situation 12 in Fig. 2, the indicatrix 14' has a principal axis which extends at a small angle to the axis transverse to the liquid crystal layer; it is, as it were, slightly tilted. A compensation layer 9 between the liquid crystal material and the polarizer 8, with indicatrix 15 which is optimal for the situation 11 will have very little effect in this case.

The invention provides optically anisotropic compensation layers 9 having such an indicatrix 15' that the birefringence is substantially entirely compensated for the more practical adjustment of, for example situation 12; as it were, the indicatrix 15' is tilted

in the same way with respect to the principal axis as the indicatrix 14'. Viewed in a direction perpendicular to the substrates, the director pattern in the optically anisotropic layer thus acquires a non-rotationally symmetrical pattern.

The director pattern in the optically anisotropic layer may be rotationally symmetrical itself, for example if a cholesteric foil having an optically anisotropic layer as described ~~in EP-A-0.423.881 is~~ used. Alternatively, discotic (disc-shaped) liquid crystal materials may be used as basic materials for the anisotropic compensation layer 9. These discotic molecules may be provided with reactive groups so as to polymerize the materials. By means of polymerization, and dependent on, for example temperature or other peripheral conditions, the desired ordering may then be provided. Here again, a layer is obtained with a refractive index n_z transverse to the anisotropic compensation layer and being smaller than that in the planes parallel to the anisotropic compensation layer ($n_x = n_y$).

By slightly tilting this foil 9 (Fig. 4a), a broken director pattern, viewed transversely to the substrates, is obtained. To avoid reflections, the interspace may be filled up with a material 10 having the same refractive index as the substrate material or as the foil material, for example UV-polymerized ethoxylated bisphenol-A diacrylate.

At larger dimensions, such a construction will become very thick. For the procedure of manufacturing the cholesteric filters, *viz.* providing a liquid chiral crystal ~~monomer as~~ a thin film on substrates, as is shown in Fig. 5 and subsequent (photo)polymerization, there are a number of variations yielding favourable results, as shown in Fig. 6. For example, the manufacturing procedure may be based on sawtooth-shaped substrates, which results in a foil 9 as is shown in Fig. 4b. The resultant optically anisotropic layer now has a sawtooth structure at both sides, the long sides of the sawtooth extending at a small angle to the substrates 3, 4. If no special measures are taken during manufacture, the directors of the molecules of the cholesteric liquid crystal material from which the foil 9 is made direct themselves parallel to these long sides, which is shown by means of the shaded structure in the optically anisotropic layer (foil) 9 in Figs. 1 and 4. The optical axis of the foil 9 now no longer coincides with the optical axis of the liquid crystal cell formed by the liquid crystal material 2 and the substrates 3 (because the director profile in at least a part of the optically anisotropic layer is provided at an angle to the boundary surfaces, the boundary surface being considered as a surface bounding the foil transverse to the foil, while surface disturbances such as the teeth of the sawtooth in this example are ignored. The director profile in the foil thus has a broken symmetry, viewed transversely to the substrate 3, 4. To avoid optical disturbance by the sawtooth pattern, the pitch of the sawtooth is chosen to be

smaller than the dimension of a pixel of the display device. The sawtooth patterns at both sides of the foil may be rotated with respect to each other, for example through 90 degrees. The total structure then has a smaller retardation.

The sawtooth structure may alternatively be provided on one boundary surface only, so that a splay deformation is introduced in the foil 9 (Fig. 4c). The directors then have an angle to a plane parallel to the substrates over a part of the thickness of the foil, so that a broken axial symmetry is obtained again. The same can be achieved by making use of flat substrates during manufacture and by inducing a pretilt on one or both surfaces when the liquid cholesteric material is being provided; upon subsequent freezing (netting) of the structure, this structure is maintained so that again a number of directors has an angle to a plane parallel to the substrates and a broken axial symmetry is obtained.

The anisotropic layers based on discotic liquid crystal materials may also be given such a structure. The directors of the discotic molecules now extend at an angle to the normal and, viewed transversely to the substrates 3, 4, the foil again has a broken symmetry.

The sawtooth structure may again be provided on one boundary surface only so that a bend deformation is introduced in the foil 9. The directors are not directed transversely to the substrates over a part of the thickness of the foil, so that a broken axial symmetry is obtained again.

During photopolymerization, there may be an electric field, denoted by the arrow 18 in Fig. 6a, perpendicular to the surfaces 16 in this example, in which the directors 17 are situated (when manufacturing cholesteric layers). Under the influence of this field (which is provided, for example on electrodes parallel to the layer to be formed, in which possibly one of the electrodes may be provided on the substrate of the liquid crystal cell), the molecules are tilted. To tilt all molecules in the same direction (uniform tilt), a substrate is preferably used which induces a pretilt in the same way as described hereinbefore. If tilting is induced by means of a magnetic field, it can be oriented obliquely to the surfaces 16, as is denoted by arrow 19 in Fig. 6b.

Without special measures, the director is situated along a helix transverse to the compensation layer which has a small pitch with respect to the thickness of the compensation layer. Such a compensator has axial symmetry, *i.e.* all directions of the director occur to a substantially equal extent; there is no preference for a given azimuth angle ϑ. This is shown by means of a broken line in Fig. 7. This axial symmetry can be broken by exposing the cholesteric layer during polymerization to a magnetic field transverse

to the layer, so that a preference for given azimuth angles is introduced, which is shown by means of the line 21 in Fig. 7.

The extent of asymmetry may be increased by adding a uniaxial foil having a small Δn to the foil 9; this may be, for example the substrate on which the monomer layer is provided (for example (stretched) cellulose triacetate or (stretched) polycarbonate). Alternatively, the layer may be slightly stretched after the polymerization has been partly finished, while the birefringence of the stretched substrate on which the monomer layer is provided may also contribute to the breaking of the symmetry.

The last-mentioned measures (influencing with an electric or magnetic field, providing a uniaxial foil having a small birefringence, stretching of the layer) may also be used for disturbing the axial symmetry in the foil in layers based on discotic materials.

The extent of "refraction" of the symmetry is also determined by the voltage range in which birefringence must be compensated so as to obtain complete extinction. For example, a range 22 in the transmission/voltage curve may be chosen around a given voltage V_{comp} (Fig. 8a) in which the position of the directors in the liquid crystal material hardly deviates from that shown in the situation 11 of Fig. 2. In this case, a slightly broken symmetry is sufficient. When a range 22' in the transmission/voltage curve is chosen around a given voltage V'_{comp} (Fig. 8b) in which the position of the directors in the liquid crystal material deviates considerably from that in the situation 11 of Fig. 2, a much stronger broken symmetry must be used. Optimum extinction can be obtained by rotating the compensation layer with respect to the liquid crystal layer, if necessary. Alternatively, the anisotropic layer 9 may be provided with areas having a more or less broken symmetry. In the first areas the viewing angle dependence is then slightly overcompensated, while it is compensated slightly too little in the other areas. The dimension of the areas is smaller than that of a pixel. In this way, a symmetrical viewing angle dependence is obtained. The invention is of course not limited to the examples shown. For example, a plurality of foils (anisotropic layers) 9 may be arranged one behind the other and, for example each of them may compensate optimally for a different given voltage V_{comp}. Alternatively, for example two foils may be provided on different sides of the liquid crystal layer.

In summary, the invention provides a liquid crystal display cell with one or more compensation layer(s) and, viewed transversely to the cell, a broken (non-rotationally symmetrical) refractive index pattern or indicatrix. To obtain a small angle dependence, the associated birefringence of the compensation layer is complementary to that associated with a given voltage across the liquid crystal cell. The compensation layer may be

manufactured in many different ways by making use of cholesteric or discotic foils for this layer.

CLAIMS:

1. A liquid crystal display device having a display cell which comprises a layer of nematic liquid crystal material between two substrates provided with electrodes, said cell being further provided with polarizers and comprising at least an optically anisotropic layer of a material having a cholesteric ordering between the polarizers, characterized in that, viewed transversely to the substrates, the director profile in the optically anisotropic layer has a non-rotationally symmetrical pattern.

2. A liquid crystal display device having a display cell which comprises a layer of nematic liquid crystal material between two substrates provided with electrodes, said cell being further provided with polarizers and comprising at least an optically anisotropic layer of a polymer material between the polarizers, characterized in that the optical axis of the optically anisotropic layer extends at an angle to a direction transverse to the substrates.

3. A liquid crystal display device as claimed in Claim 1 or 2, characterized in that the optical axis of the optically anisotropic layer is substantially parallel to the direction of the directors of the liquid crystal molecules, taken at an average across the layer of nematic liquid crystal material at a given voltage.

4. A liquid crystal display device as claimed in Claim 3, characterized in that the transmission is substantially zero at the given voltage.

5. A liquid crystal display device as claimed in any one of Claims 1 to 5, characterized in that the optically anisotropic layer comprises a layer of polymer material having a cholesteric ordering.

6. A liquid crystal display device as claimed in Claim 5, characterized in that the director profile in the optically anisotropic layer is parallel to boundary surfaces of the optically anisotropic layer, and the optically anisotropic layer is provided at an angle to one of the substrates.

7. A liquid crystal display device as claimed in Claim 5, characterized in that the director profile in at least a part of the optically anisotropic layer is provided at an angle to the substrates.

8. A liquid crystal display device as claimed in Claim 5, characterized in that there is a preferred direction within the director profile.

9. A liquid crystal display device as claimed in Claim 5, characterized in that the director profile in the optically anisotropic layer locally extends across only a part of the thickness of the layer.

10. A liquid crystal display device as claimed in any one of Claims 5 to 9, characterized in that the pitch of the cholesteric material is smaller than 0.25 μm.

11. A liquid crystal display device as claimed in any one of Claims 1 to 4, characterized in that the optically anisotropic layer comprises a layer of polymerized discotic liquid crystal material.

12. A liquid crystal display device as claimed in Claim 11, characterized in that the average direction of the director in the optically anisotropic layer is transverse to the boundary surfaces of the optically anisotropic layer, and the optically anisotropic layer is provided at an angle to one of the substrates.

13. A liquid crystal display device as claimed in Claim 11, characterized in that the average direction of the director in the optically anisotropic layer is provided at an angle to the direction transverse to the substrates.

14. A liquid crystal display device as claimed in Claim 11, characterized in that the average direction of the director in the optically anisotropic layer varies.

15. A liquid crystal display device as claimed in Claim 5 or 11, characterized in that the optically anisotropic layer has a sawtooth structure on at least one of its boundary surfaces.

16. A liquid crystal display device as claimed in Claim 15, characterized in that both boundary surfaces of the optical anisotropic layer have a sawtooth structure whose direction is rotated with respect to each other.

17. A liquid crystal display device as claimed in Claim 15 or 16, characterized in that the optically anisotropic layer also comprises a layer having a uniaxial symmetry.

18. A retardation foil comprising an optically anisotropic layer of a material having a cholesteric ordering, characterized in that, viewed transversely to the foil, the director profile in the optically anisotropic layer has a non-rotationally symmetrical pattern.

19. A retardation foil comprising an optically anisotropic layer of a polymer material, characterized in that the optical axis of the optically anisotropic layer extends at an angle to a direction transverse to the substrates.

20. A retardation foil as claimed in Claim 18 or 19, characterized in that the optically anisotropic layer comprises a layer of a polymer material having a cholesteric

ordering.

21. A retardation foil as claimed in Claim 20, characterized in that the director profile in at least a part of the optically anisotropic layer is provided at an angle to the boundary surfaces.

22. A retardation foil as claimed in Claim 20, characterized in that there is a preferred direction within the director profile.

23. A retardation foil as claimed in Claim 20, characterized in that the director profile in the optically anisotropic layer locally extends across only a part of the thickness of the layer.

24. A retardation foil as claimed in any one of Claims 20 to 23, characterized in that the pitch of the cholesteric material is smaller than 0.25 micrometer.

25. A retardation foil as claimed in Claim 19, characterized in that the optically anisotropic layer comprises a layer of polymerized discotic liquid crystal material.

26. A retardation foil as claimed in Claim 25, characterized in that the average direction of the director in the optically anisotropic layer is transverse to the boundary surfaces of the optically anisotropic layer, and the optically anisotropic layer is provided at an angle to one of the substrates.

27. A retardation foil as claimed in Claim 25, characterized in that the average direction of the director in the optically anisotropic layer is provided at an angle to the direction transverse to the substrates.

28. A retardation foil as claimed in Claim 25, characterized in that the average direction of the director in the optically anisotropic layer varies.

29. A retardation foil as claimed in Claim 20 or 25, characterized in that the optically anisotropic layer has a sawtooth structure on at least one of its boundary surfaces.

30. A retardation foil as claimed in Claim 29, characterized in that both boundary surfaces of the optical anisotropic layer have a sawtooth structure whose direction is rotated with respect to each other.

31. A retardation foil as claimed in Claim 29 or 30, characterized in that the optically anisotropic layer also comprises a layer having a uniaxial symmetry.

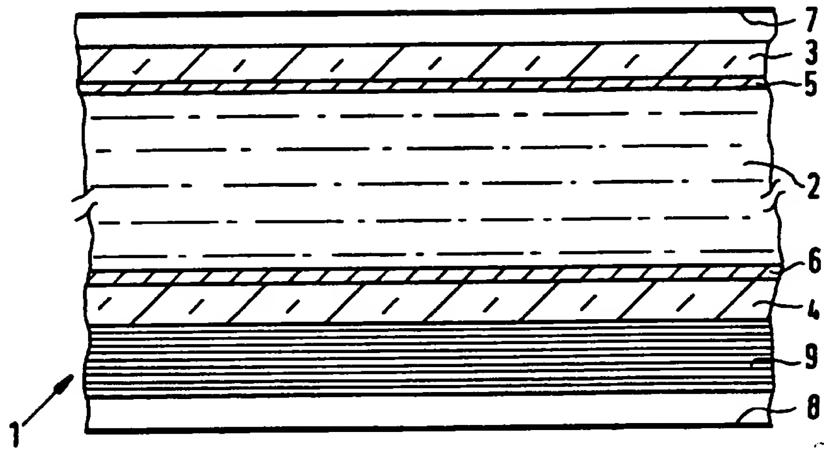


FIG.1

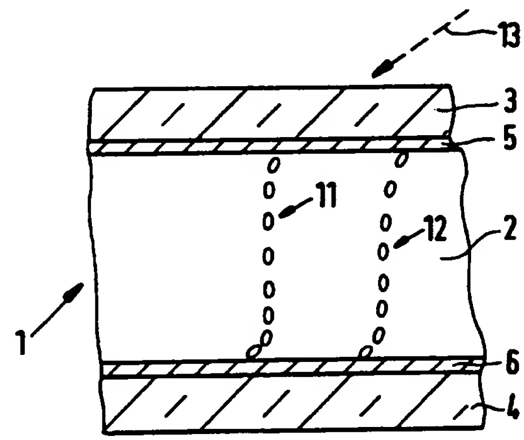


FIG.2

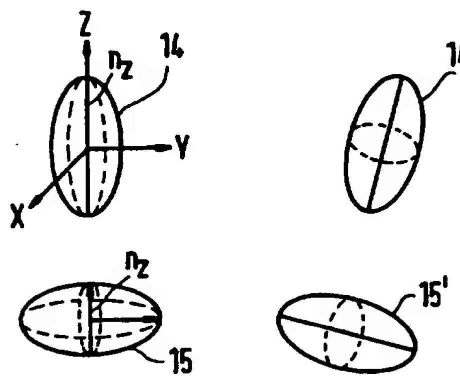


FIG.3

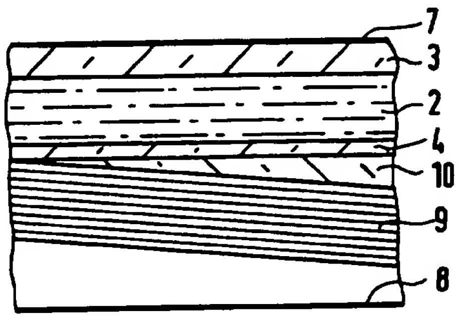


FIG.4a

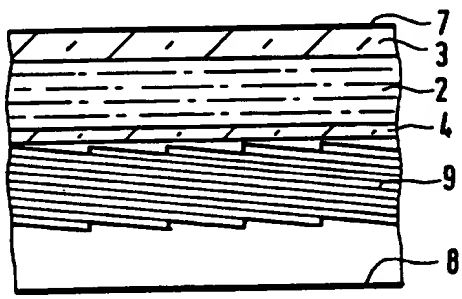


FIG.4b

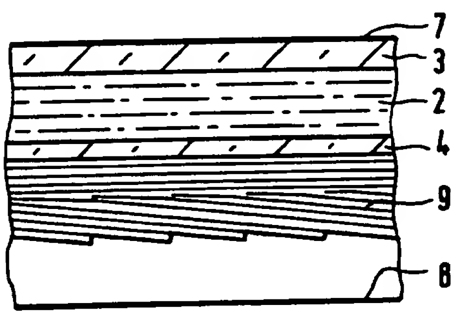
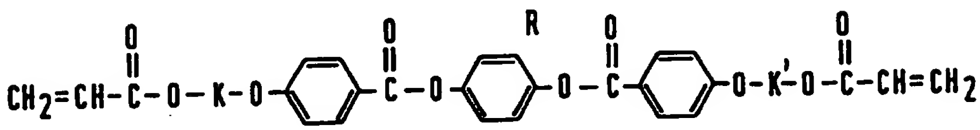


FIG.4c



$K = (CH_2)_3 - C^{*}H(CH_3) - (CH_2)_2$

$K' = (CH_2)_2 - C^{*}H(CH_3) - (CH_2)_3$

FIG.5

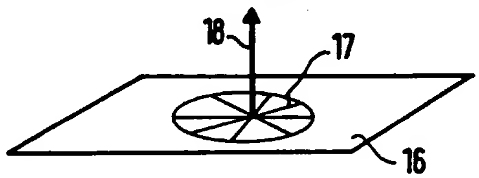


FIG.6a

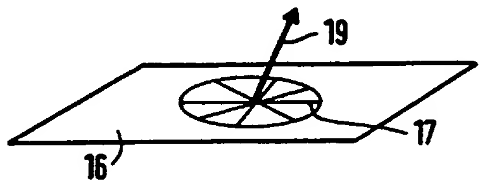


FIG.6b

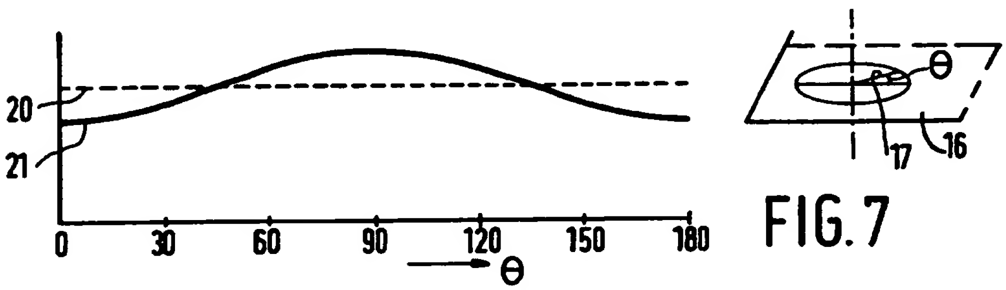


FIG.7

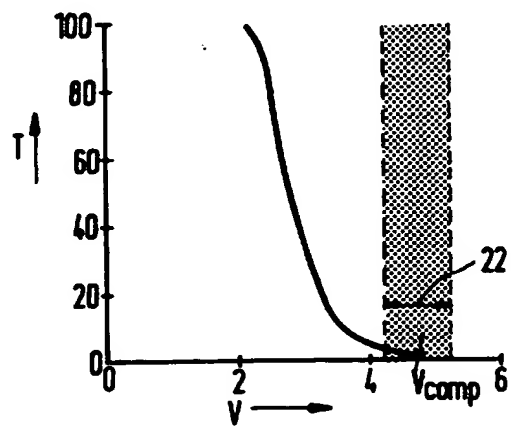


FIG.8a

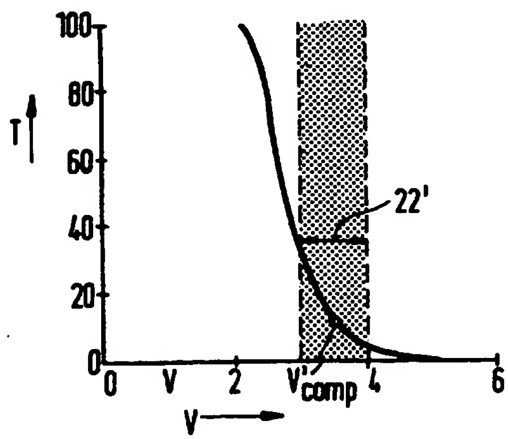


FIG.8b